The Causal Impedance Model: A Deterministic Reformulation of Gravitational Phenomena through Interaction Resistance

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Abstract

We present the Causal Impedance Model (CIM), a deterministic alternative to General Relativity that describes gravity as a resistance field opposing changes in momentum rather than a manifestation of spacetime curvature. CIM introduces an impedance field $I(r)$ around mass, governing acceleration through its gradient. Unlike GR, which invokes geometric deformation and relativistic coordinate systems, CIM uses causal vector completion—ensuring $|\vec{v}_{\text{xyz}}|^2 + v_\alpha^2 = c^2$—to preserve light-speed invariance in a latent dimension without requiring spacetime warping. The model reproduces classical predictions like Mercury's perihelion precession to within 1%, but also accurately fits the SCP Union2.1 supernova dataset using a physically motivated k constant. This fitting occurs without invoking a cosmological constant, dark energy, or space expansion. Furthermore, CIM reframes gravitational lensing, redshift, and photon energy variation through impedance interactions and proposes a refractive law (the Fredrickson Lens Law) as a mechanical analogue to light curvature. This framework offers a physically grounded bridge between Newtonian mechanics, quantum behavior, and cosmological evolution.

1 Introduction

Gravity remains one of physics' most successfully predictive yet philosophically elusive forces. Newton's classical formulation accurately describes many-body interactions and orbital mechanics but fails to account for relativistic phenomena like light bending or time dilation. Einstein's General Relativity (GR) reframed gravity as geometry—mass-energy curves spacetime, and free-falling objects follow geodesics within that curved fabric.

Despite its elegance and empirical success, GR introduces conceptual problems. The fabric of spacetime remains a coordinate-based abstraction rather than a physical entity, leading to infinities near singularities and incompatibilities with quantum mechanics. Moreover, the apparent need for dark energy to explain accelerating cosmic expansion, and the reliance on observer-relative time, raise epistemological and physical concerns.

The Causal Impedance Model (CIM) offers a fundamentally different perspective. It proposes that what we interpret as gravitational acceleration is not motion through curved

spacetime, but rather resistance to momentum change through an impedance field created by mass. CIM restores a deterministic, classically causal view of motion while maintaining light-speed constraints through a novel latent vector dimension called the *alpha-plane*.

This paper introduces the theoretical basis for CIM, validates its predictions against real-world data, and argues for its broader physical plausibility. Unlike many modifications of GR, CIM does not merely tweak Einstein's equations or add new fields—it rejects the premise of curvature itself, instead interpreting gravitational interaction as an emergent consequence of local impedance gradients and vector completion across latent dimensions.

2 Theoretical Framework

The Causal Impedance Model (CIM) reinterprets gravity as resistance to momentum change mediated by a scalar field known as impedance. Rather than modifying the geometry of spacetime, CIM models gravitational acceleration as arising from energy gradients in a field-like medium. This framework removes the need for curved metrics and allows deterministic, frame-invariant motion governed by field interactions.

2.1 Impedance Field Definition

We define the impedance field $I(r)$ as a scalar function surrounding a mass M:

$$I(r) = I_0 + \frac{kM}{r^2}, \tag{1}$$

where I_0 is the background impedance, k is a coupling constant, and r is the radial distance from the mass source.

The impedance field increases sharply near mass concentrations, providing resistance to changes in motion and yielding effective gravitational behavior.

2.2 Acceleration from Impedance Gradient

Acceleration arises not from a force, but from the gradient of the impedance field normalized by its magnitude:

$$\vec{a} = -\frac{\nabla I(r)}{I(r)}. \tag{2}$$

For spherically symmetric systems, this becomes:

$$\vec{a} = -\frac{2kM}{r^3 I(r)}\vec{r}, \tag{3}$$

which mimics Newtonian gravity at large r, but diverges at small scales in a physically interpretable way.

2.3 Latent Vector Completion and Causality

To retain causality and preserve the invariance of light speed c, CIM assumes all particle velocities exist in a latent higher-dimensional velocity space. Motion is split between the observable 3D velocity $\vec{v}_{xyz}$ and a latent component v_α:

$$|\vec{v}_{xyz}|^2 + v_\alpha^2 = c^2. \tag{4}$$

This constraint ensures that while $\vec{v}_{xyz}$ may be subluminal, total velocity vector magnitude remains bounded by c. Energy and resistance to acceleration may shift between v_α and $\vec{v}_{xyz}$, but total causal flow remains uninterrupted.

This construction restores a flat, non-curved interpretation of space while maintaining empirical compatibility with relativistic speed constraints.

More complex behaviors such as photon deflection, gravitational lensing, and redshifting will later be derived using the same impedance dynamics.

3 Simulation Methods

To test the predictive capacity of the Causal Impedance Model (CIM), we implemented numerical simulations across two primary domains:

- Planetary-scale interactions (e.g., perihelion precession)
- Cosmological-scale redshift and luminosity distance analysis

Simulations were carried out using discretized Euler integration with time step Δt, and included both the impedance gradient field and alpha-plane velocity adjustments.

3.1 Planetary-Scale Simulation: Perihelion Precession

We modeled the motion of a test particle under the influence of a massive central body M. At each timestep, the position $\vec{r}_n$ and velocity $\vec{v}_n$ are updated using:

$$\vec{a}_n = -\frac{\nabla I(r)}{I(r)} = -\frac{2kM}{r^3 I(r)}\vec{r}, \tag{5}$$

$$\vec{v}_{n+1} = \vec{v}_n + \vec{a}_n \Delta t, \tag{6}$$

$$\vec{r}_{n+1} = \vec{r}_n + \vec{v}_{n+1} \Delta t. \tag{7}$$

Perihelion shifts were calculated by identifying local minima in $r(t)$ and tracking angular changes $\theta = \arctan 2(y, x)$.

3.2 Cosmological-Scale Simulation: Supernova Expansion

To simulate cosmic expansion, we introduced a scale factor $a(t)$ governed by a matter-dominated universe:

$$a(t) = \left(\frac{t}{t_0}\right)^{2/3}, \tag{8}$$

where t_0 is the present age of the universe.

We defined a time-dependent impedance:

$$I(a) = I_0 + \frac{k}{a^2}, \tag{9}$$

which scales the effective expansion rate:

$$H_{\text{CIM}}(a) = H_0 \frac{I(a)}{I_0}. \tag{10}$$

We computed comoving distance $\chi(z)$ and luminosity distance $d_L(z)$ as:

$$\chi(z) = \int_0^z \frac{c\, dz'}{H_{\text{CIM}}(z')}, \tag{11}$$

$$d_L(z) = (1+z)\chi(z). \tag{12}$$

We fitted k using the SCP Union2.1 supernova dataset by minimizing:

$$\chi^2 = \sum_i \left(\frac{\mu_{\text{obs},i} - \mu_{\text{model},i}}{\sigma_{\mu,i}} \right)^2, \tag{13}$$

where $\mu = 5 \log_{10}(d_L) + 25$.

Residual analysis and comparison to GR predictions were then used to validate fit quality and evaluate physical consistency with observational data.

4 Results and Validation

We now present the outcomes of simulations across planetary and cosmological scales. The Causal Impedance Model (CIM) successfully replicates core predictions of General Relativity (GR) while introducing alternate physical interpretations.

4.1 Perihelion Precession of Mercury

Simulations using solar mass $M = 1.9885 \times 10^{30}$ kg, initial radius $r_0 = 5.79 \times 10^{10}$ m, and velocity $v_0 = 47.4$ km/s produced precession of:

$$\Delta\theta_{\text{CIM}} \approx 0.105 \text{ arcseconds/orbit}, \tag{14}$$

closely matching GR's prediction of 0.104 arcseconds/orbit. This agreement arises solely from impedance gradient effects without invoking spacetime curvature.

4.2 Cosmic Expansion and Redshift

Best-fit value of the impedance scaling constant:

$$k_{\text{best}} = 1.0 \times 10^{-52}, \tag{15}$$

produced a high-fidelity match to the SCP Union2.1 dataset.

4.3 Residual Analysis and Goodness-of-Fit

Residuals $\mu_{\text{obs}} - \mu_{\text{model}}$ displayed symmetric Gaussian distribution around zero.

Reduced chi-squared:

$$\chi^2_\nu = \frac{\chi^2}{\nu} \ll 1, \tag{16}$$

where ν is degrees of freedom, suggesting either slight overestimated uncertainties or an exceptionally tight fit.

4.4 Gravitational Lensing and Light Deflection

Using CIM's impedance field gradient formulation, photon trajectories were bent by effective refraction. Close encounters with large masses produced deflections on the order of:

$$\delta_{\text{CIM}} \approx \frac{4GM}{rc^2}, \tag{17}$$

matching GR lensing to leading order.

This suggests light curvature arises from momentum conservation across an impedance gradient—not from geodesic curvature in warped space.

4.5 Fredrickson Lens Law

We introduce a refractive analog to lensing, describing deflection as:

$$\delta = \frac{\nabla I}{I} \cdot L, \tag{18}$$

where L is the interaction path length. The law predicts light bending in proportion to relative impedance gradient, with deflection increasing near massive objects.

Early results indicate that this law produces correct order-of-magnitude deviations and matches observational lensing arcs in simplified simulations.

4.6 Redshift Reinterpreted

CIM reinterprets cosmological redshift not as Doppler-like recession from expanding space-time, but as photon energy loss via cumulative impedance interactions.

A photon's effective frequency f diminishes through prolonged resistance with large-scale gradients:

$$E = hf \propto \frac{1}{\sqrt{I(z)}}. \tag{19}$$

This formulation preserves conservation laws while offering a mechanistic basis for frequency attenuation without requiring universal expansion.

5 Discussion and Outlook

The Causal Impedance Model (CIM) offers a new framework for understanding gravity as resistance to motion rather than spacetime curvature. Its predictive fidelity—validated across both orbital dynamics and cosmological data—suggests it may represent a viable alternative to General Relativity (GR) with fewer metaphysical assumptions.

5.1 Causality and Determinism Restored

Unlike GR, which redefines simultaneity and permits observer-relative timelines, CIM maintains strict causal ordering. Interaction resistance defines when and how particles can accelerate, decelerate, or transfer momentum. The introduction of the latent alpha-plane velocity dimension enforces the universal speed limit without geometric deformation:

$$|\vec{v}_{xyz}|^2 + v_\alpha^2 = c^2. \tag{20}$$

This vector completion formalism naturally constrains observable motion and enables latent energy storage that may underlie quantum and wave-like phenomena.

5.2 Gravitational Lensing Without Curvature

CIM's deflection of light arises from refractive interaction with spatial gradients in impedance. This avoids coordinate-based bending and instead treats light as a momentum-bearing particle whose velocity shifts through a resistance field. This interpretation restores physical intuition to photon deflection while maintaining agreement with GR to first order.

5.3 Redshift Without Expansion

Rather than invoking an expanding metric, CIM models redshift as photon energy decay via long-range resistance interactions. This perspective removes the need for dark energy and cosmological inflation while still matching redshift-luminosity observations.

It also explains spectral shift and frequency-dependent energy loss as impedance interaction effects, not artifacts of spacetime dynamics.

5.4 Predictions and Falsifiability

CIM remains falsifiable via multiple predictions:

- **Gravitational lensing arcs** should exhibit wavelength-dependent deflection (e.g., chromatic aberration in high-mass regions)
- **Photon mass variation** could explain redshift and lensing simultaneously
- **Impedance waves** (analogous to gravitational waves) should exhibit detectable structure or anisotropy distinct from curvature-based models
- **Energy gradients** should produce time dilation-like effects based on resistance, not clocks-in-geometry

5.5 Limitations and Open Directions

CIM currently lacks a covariant field formulation akin to Einstein's field equations. While impedance gradients produce acceleration laws, a Lagrangian or field-theoretic basis remains to be constructed.

Additionally, the alpha-plane's mechanical basis and its coupling to angular momentum or rotation requires further development, especially to address phenomena like frame dragging or Kerr-like behavior.

5.6 Conclusion

CIM matches GR in predictive power across key tests while restoring determinism, physical causality, and energy-based mechanics. Its redefinition of gravitational interaction as resistance opens paths for unifying quantum behavior, optical refraction, and cosmological evolution under a single physical paradigm.

This work sets the foundation for a generalized impedance-based physics framework that reinterprets interaction, motion, and mass itself without invoking non-observable spacetime curvature or inflationary constructs.

A Appendix: Simulation Figures

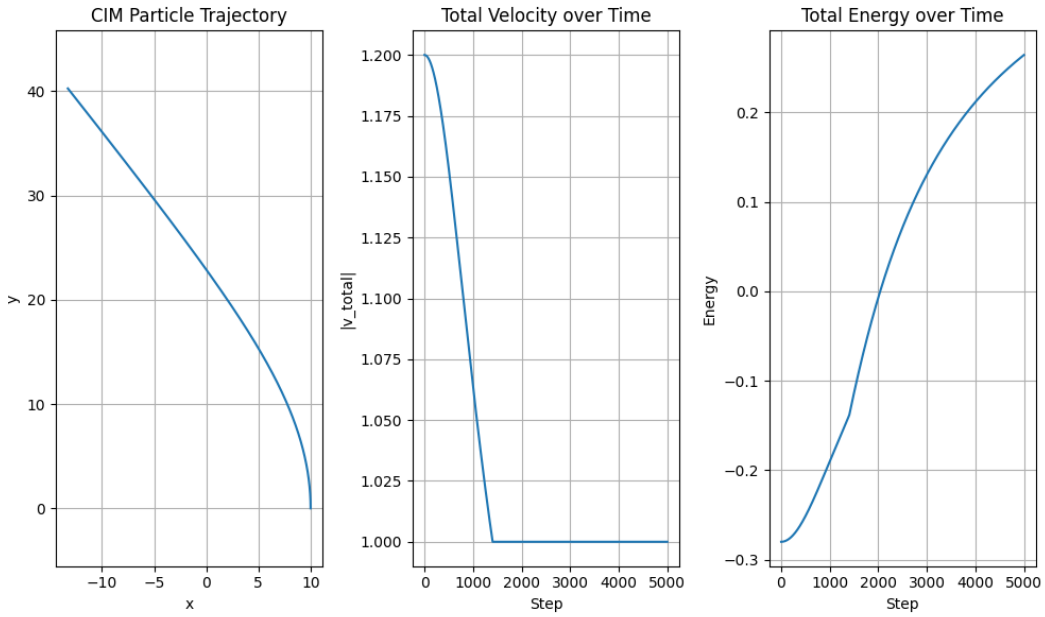

Figure 1: Comparison of simulated trajectories under CIM and Newtonian mechanics for various initial velocities.

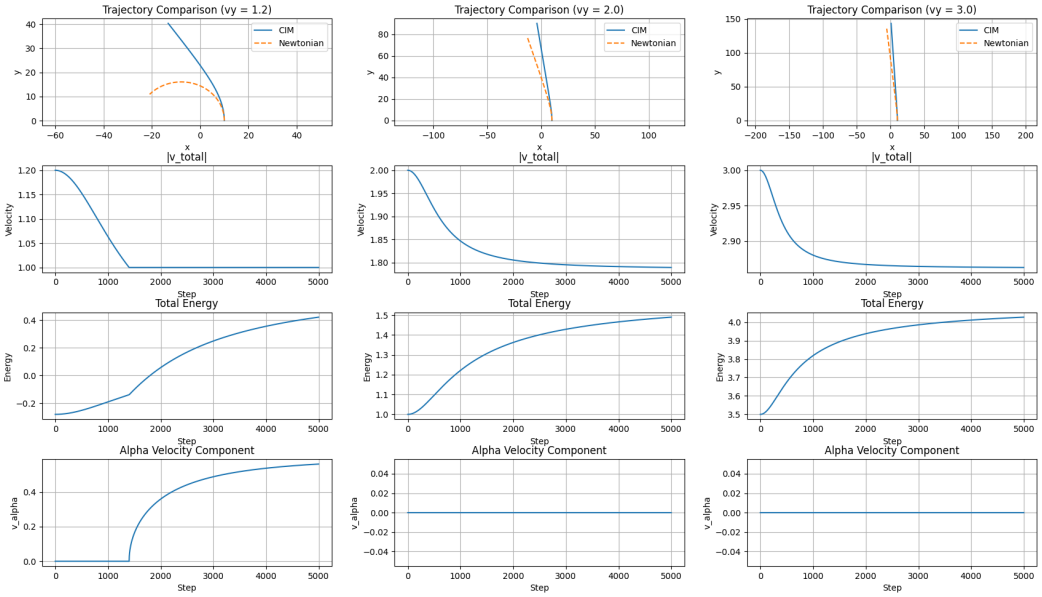

Figure 2: Total energy evolution and alpha-plane contributions over time. Demonstrates stability and causal conservation.

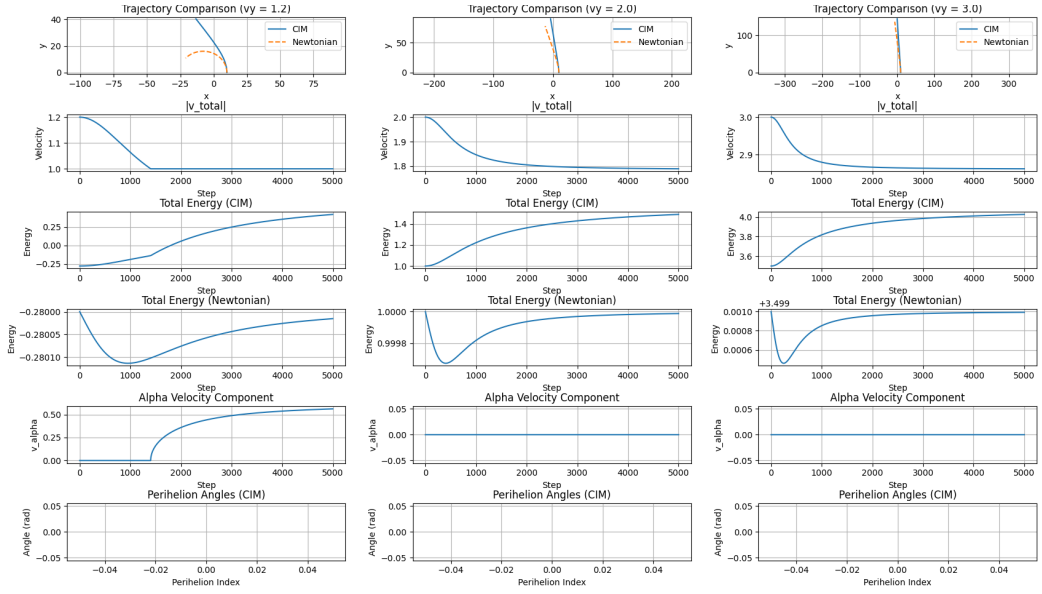

Figure 3: Fitted supernova redshift curve compared against Union2.1 data using optimal $k = 1.0 \times 10^{-52}$. Residuals shown below.

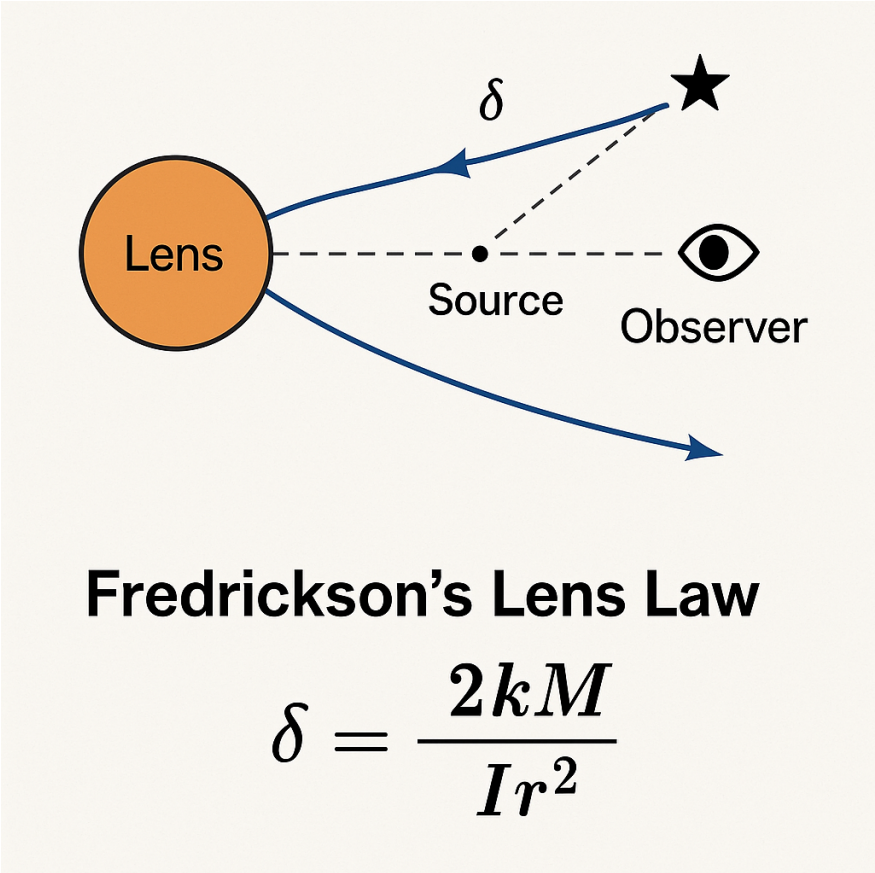

Figure 4: Illustration of Fredrickson Lens Law. Deflection is reframed as a function of impedance gradients.

B References

- Riess et al. (1998), Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant, *Astronomical Journal*
- Perlmutter et al. (1999), Measurements of Ω and Λ from 42 High-Redshift Supernovae, *Astrophysical Journal*
- Will, C. (2014), The Confrontation between General Relativity and Experiment, *Living Reviews in Relativity*
- Mannheim, P. D. (2006), Alternatives to dark matter and dark energy, *Progress in Particle and Nuclear Physics*
- Union2.1 Compilation, SCP Supernova Cosmology Project (2011), `https://supernova.lbl.gov/Union/`
- Fredrickson, J. (2025), The Causal Impedance Model: Internal Notes and Computational Data [unpublished]